503.00 METAL REINFORCEMENT

General

Reinforced concrete is a mixture of concrete and steel reinforcement. Concrete is weak in tension and cracks easily when it shrinks or creeps under sustained loading. It is a brittle material. When concrete fails, it breaks suddenly without warning. Steel, on the other hand, is 100 times stronger in tension than concrete; is 6 times stiffer; and will stretch 17 times more than concrete before failing. Steel reinforcement provides reinforced concrete the tensile strength, stiffness, and ductility needed to make it an efficient, durable, versatile, and safe building material.

For reinforced concrete to work as the Designer intended, the Inspector and Resident Engineer must ensure that reinforcing steel placed in a structure is:

- the correct grade and type of steel;
- the correct size, shape and length;
- placed in its specified location and spaced properly;
- tied and spliced together properly;
- clean and will get an adequate cover of concrete in all directions; and
- placed in the correct quantities.

The Inspector should check the steel closely upon arrival. Any discrepancies in grade, type, size, shape or lengths should be reported immediately to the Contractor, the Bridge Section and /or the Consultant Designer.

The Resident Engineer should ensure that all the Inspectors are trained and prepared to inspect, sample and document all phases on the rebar placement. Appropriate reference and training materials should be readily available to Inspectors.

Information on identifying markings and placing rebar, splices, bar supports, and wire mesh can be found in the Concrete Reinforcing Steel Institute (CRSI) *Manual of Standard Practice* (a copy is available at Bridge Section and hopefully in each District). Inspectors that inspect reinforcing on ITD projects should have access to the latest copy of *Placing Reinforcing Bars* published by the CRSI as well. Additional information on these manuals, questions, and video training supplements can be initiated by referencing the CRSI web site at http://www.crsi.org/ .

Primary and Secondary Reinforcement

In any reinforced concrete structure, the reinforcing steel can be divided into two categories. *Primary reinforcement* is the steel in the concrete that helps carry the loads placed on a structure. Without this steel, the structure would certainly collapse. Sometimes primary reinforcement is referred to as *structural steel*. The steel placed in a structure that enhances the durability and holds the structure together is known as *Secondary reinforcement*. It provides the resistance to cracking, shrinkage, temperature changes, and impacts necessary for a long service life of the structure. Sometimes secondary reinforcement is referred to as *temperature steel*.

For example, the steel on the backfill face of a cantilever retaining wall that retains soil and resists the loads induced by the soil is primary or structural in nature. Whereas the steel in the front face of a wall functions more for crack and shrinkage control. Its main job is to hold the concrete together.

It's important for the Resident Engineer and Inspector to become familiar with the primary and secondary steel reinforcement in the structure. Not only does this help the Inspector visualize how the steel should look, but it helps in getting compliance from the Contractor by being able to discuss the reasons for good placement procedures and how each bar in the structure is intended to function. The Designer can help identify which steel is primary and which is secondary reinforcement. This knowledge is also important in determining what course of action to take if defective or failing material is found for rebar already placed and covered with concrete. Generally non specification rebar should be rejected but it may be accepted with a price adjustment in some cases as discussed later.

Reinforcing Steel Changes in the Field

Contractors may request changes in how reinforcing steel is specified and designed to facilitate construction. These changes can include:

- moving bars;
- bending bar;
- substituting bars for different sizes, grades or types;
- cutting or torching bars;
- welding bars; and
- using different splice details or splice locations.

Any requests that would change the location, size, shape, type, grade, length, splice location or that would change the design of the steel reinforcement in a structure must **have the approval of the Designer**.

Most reinforcing steel for ITD structures is specified as Type A615M (billet steel), Grade 60 (420). Occasionally the Contractor may want to substitute A706 steel for the A615 type. This kind of substitution is generally acceptable as long as the grade of steel stays the same and there are no changes in bar sizes or lengths. However, some types of reinforcing steel such as ASTM A616 (rail steel) and A617 (axle steel) are not acceptable substitutes.

Occasionally, Contractors may desire to furnish higher grade steel than what is specified. While this may sound innocent enough there may be an issue. For example, if the Contractor proposes to use Grade 75 (520) steel for Grade 60 (420) a problem may exist. Grade 75 (520) steel has a much higher yield strength than Grade (60) 420 and could adversely affect how a structure behaves during a failure. Likewise when the Contractor wants to substitute larger bar sizes over what is specified, problems can be created. Larger bars can cause clearance problems and in some cases may lead to over-reinforcement of a concrete section (a violation of AASHTO bridge specifications).

As mentioned earlier, steel reinforcement can be divided into primary and secondary reinforcement. Even minor changes in either category can have a profound impact on the behavior and longevity of the structure. This is why it is important to contact the Designer on rebar changes so the impacts can be accurately assessed and accounted for in the design. Furthermore, a change order must be executed showing the concurrence of the Structural

Designer and the Headquarters' Materials Section for any change in the rebar material specification.

The Resident Engineer can deal with changes in how steel is tied, cleaned, supported, stored, and handled with input from the Bridge Section or Consultant Designer as needed.

Welded Wire Fabric (Wire Mesh)
Wire mesh is sometimes specified by a Designer to control shrinkage and cracking in a concrete slab or wall.

CONSTRUCTION REQUIREMENTS

Bending Schedules and Bar Lists
Bar bending diagrams and bar lists are shown in the Project Plans. The Contractor needs to verify the bar lists within the structure drawings prior to ordering or fabricating the reinforcing steel. The intent is to get the Contractor to review these lists before the steel is made and shipped to the project. Any major discrepancies should be brought to the attention of the Resident Engineer and the Designer. This proactive approach will help prevent any delays to the project due to bars that have been cut the wrong length, bent the wrong way, or specified as the wrong size. Waiting until the steel arrives on the job to begin checking bar dimensions is a practice that the Department would like to avoid.

On every set of bridge plans there is a diagram with notations describing the requirement for rod hooks and bends. A "hook" refers to the 90E, 135E or 180E bending of a reinforcing bar. A "bend" refers to any other degree of bend. Reference should be made to this diagram when inspecting metal reinforcement. Following is a list of the types and purposes for which metal reinforcement is used.

- Longitudinal Bars - Reinforcing steel bars which run length-wise of a member.
- Transverse Bars - Reinforcing steel bars that run across the width of a member.
- Stirrups - "U" or "W" shaped bars placed in a vertical plane used to resist shear in structural members.
- Tie Bars - Act to resist stress and hold other stress bars and structural members in position.
- Dowels - Short bars extending from one member into another to transfer stresses from one member into another.
- Spiral Reinforcement - Spiraled hoops of reinforcing steel used on certain types of columns.
- Temperature and Shrinkage Steel - Usually 10 M (#4) bars at 450 mm (18 in.) spacing placed in lieu of stress bars to resist tension cracking due to curing and temperature shrinkage.

When bars arrive on the job, they are normally bundled and tagged. Each bundle will include all bars of a particular bend or schedule occurring in a certain portion of the structure. Each bar or bundle will bear a tag indicating the "mark" of the bar or bars. Some bars, all of a certain "mark," will be coded by a dab of paint on the end. This is to facilitate placement and identification.

Bending, Heating, and Cutting Bars

The inspector should check the rebar upon arrival at the job site to see that the bending has been done in such a degree of accuracy that placement could be made within the required tolerances. Items involving several bends such as stirrups are difficult to bend at the plant and these dimensions must be exact if the rest of the placement is to be correct. Rejecting reinforcement due to improper bending should be done prior to placement.

Contractors may want to field bend bars to simplify reinforcing steel installation or to improve access around a structure. Grade 40 (300) bars smaller than # 8 can be bent out of the way and then re-bent to their final shape when done so per the standard specifications.

If the bars have already been bent once in the shop, only one bend is allowed in the field. Repeated bending of bars weakens the steel at the bends due to metal fatigue. (This is similar to what happens every time you bend a coat hanger or a paper clip back and forth—the repeated bending action weakens the steel until it breaks.)

Heating the steel to bend it is only acceptable when done so per the Standard Specifications. The heat, if not strictly controlled and closely monitored, produces a metallurgical change of the steel. Quenching or rapid cooling of bars heated cherry red produces hardening and brittleness in the steel and must not be permitted This change results in a *notching effect* because too much heat will cause a permanent and local weakening of the steel's crystalline structure just like an actual notch in the steel. Normal, still-air cooling is recommended when bars are heated for bending.

Cutting or torching bars because they are a hindrance to steel installation or concrete placement must not be allowed without the approval of both the Structure Designer and the Resident Engineer.

Cutting the bars and then splicing them after they are out of the way is not allowed. The problem with cutting the bars and then splicing them has to do more with the splicing than the cutting of the bar. If the bar has to be spliced, the type of splice and the location of the splice should be discussed with and approved by the Designer before the bar is cut. Many times, Contractors want to cut rebar at locations where stresses in the steel are too high or insufficient bar length is available after the cut to fully develop the splice. These are the reasons why the Designer must be involved in any bar cutting decisions.

Rebar Cover and Clearance

Reinforcing steel must have adequate concrete cover near any exposed surface. This cover is needed to prevent corrosion of the reinforcing steel due to moisture, atmospheric conditions (like high humidity), and reactive soils. The Project Plans should clearly indicate the amount of cover required for reinforcing steel. If the Plans do not, the Designer should be contacted. AASHTO and ACI have minimum cover requirements on all reinforcing steel.

Adequate clearance is needed between reinforcing bars so all of the concrete mix can completely surround the bar. When bars are spaced to close together, two things can happen:

1. An air void can develop between the bars because there is not enough room for the concrete to flow between the bars. This void severely weakens reinforced concrete locally

because there is no concrete bonded to the steel. The void also causes stress concentrations in the surrounding concrete because the concrete must transfer additional stresses that the void cannot.

2. The area between the bars is filled only with mortar, and is void of coarse aggregate.

The problems with only having mortar between the bars include:

1. A reduced shearing strength in the mortar due to the absence of coarse aggregate;
2. Increased stresses in the steel as the mortar tries to shrink around the bars in the absence of course aggregate; and
3. Surrounding areas of weakened concrete that have too much coarse aggregate and not enough mortar.

ITD’s Standard Specifications do not specifically limit the clearance between individual bars. Instead they limits the maximum size of coarse aggregate in the concrete mix based on the minimum rebar clearance. In other words, the Contractor must adjust the concrete mix design to fit the minimum rebar clearances in the structure. The Inspector’s responsibility is to check areas of minimum rebar clearance and verify that the Contractor’s concrete mix will meet specifications. If the mix does not, either the Contractor submits a new mix design or the Designer is contacted about moving bars so the Contractor’s mix can adequately coat the bars.

Common locations where rebar congestion is a problem are:

1. Lap splices of longitudinal bars and
2. Column and cap beam connections where the cap beam reinforcing steel crosses the column steel protruding into the cap.

Sometimes cover problems with reinforcing steel are the results of errors in the formwork rather than errors in steel placement. If a cover problem does not seem to be the result of improper rebar installation then check the dimensions of the forms for the correct forming tolerances.

Sampling, Acceptance and Price Adjustments

As soon as reinforcing steel is delivered to the project the Inspector should determine if the bars are of the proper size and length and if the bends and bend dimensions are in accordance with the Project Plans and the tolerances shown therein.

Steel bars, steel wire, welded wire fabric, and other structural steel shapes used as reinforcement must be certified as conforming to the specifications and verified by testing **before** being covered with the concrete. Random samples for testing must be taken by the Inspector in accordance with the Contract Specifications and *Quality Assurance Manual* Encourage the contractor to wait for the results before installing. Should the contractor elect to install before the results of the verification testing ensure he understands that he installs at his own risk per subsection 106.03 of the Standard Specifications.

One important point about rebar sampling that should be stressed: precut bars furnished by the supplier as "sample bars" are not acceptable. Sample bars for verification testing must be removed from a steel shipment at random when delivered to the project site. These samples should be shipped promptly to the Central Materials Lab for testing maintaining a positive chain of custody by ITD staff or an independent carrier. Do not allow the contractor to take possession of and/or transport the samples.

Occasionally rebar is placed and covered before the results of the verification testing are known. In these cases the judgment as to rejecting the work entirely or accepting with a major price adjustment must be well thought out as it could have major ramifications as to the serviceability of the bridge, federal participation and claims. In order for this judgment to be made the following information must be sent to Headquarters Construction, Bridge and Materials for review:

1) The project name and lead key.
2) The structure/ bridge or place where the failing bar is located (e.g. US-95 MP 12.1).
3) Where the failing rebar is at (e.g. deck, pier etc.).
4) What was the grade and size of the bar (e.g. grade 60 size 4)?
5) How did it fail? (yield point, tensile strength, cold bending)
6) What was the magnitude of the failure (e.g. acceptable tensile strength for grade 60 is 90,000 psi, bar failed at 89,000 psi)
7) What was the purpose of the rebar? (Primary {structural} or Secondary {temperature} or both)
8) Was it epoxy coated?
9) When was it delivered?
10) When were the samples sent for testing?
11) When were the test results given to the contractor?
12) When (date range) did the contractor install the failing rebar?
13) How much did the failing rebar weigh?
14) What was the contract cost of each item that the rebar was installed in?

After placement of the steel in the structure, a complete final inspection must be made and documented.

Bar Supports

Adequate support for reinforcing steel must take into account not only the weight of the steel, but the stresses and strains encountered while placing the concrete as well. The Concrete Reinforcing Steel Institute publication, *Placing Reinforcing Bars*, contains recommended spacing for metal chair supports. Regardless of the recommendations, there must be enough supports to keep the reinforcing steel within the placement tolerances and to keep it from deflecting under construction loading (concrete pours and foot traffic usually) until it is covered with concrete.

Chairs should be observed to detect whether they are bending or are indenting the form material. It may be necessary to use more chairs or chairs with broader feet to carry the load exerted by the reinforcing steel and the ironworkers. Heavy rebar cages containing large bar sizes are candidates for bar support inspection by the Inspector. Wall and column reinforcement should be checked for adequate lateral support to prevent the reinforcement from being pushed against the forms during concrete placement.

The Resident Engineer and Inspector should pre-approve all bar supports and bar support methods in advance of any steel placement (preferably when the bar bending diagrams are approved).

If precast mortar blocks are used as bar supports, the blocks must have a compressive strength that meets or exceeds the strength of the concrete poured around them. The Inspector must take one sample of precast mortar blocks for every 50 placed and send them to the Central Materials Lab for strength testing.

Splicing and Lapping
Reinforcing steel is often specified in lengths that are too long for the steel to be delivered and placed as a single piece. As a result, two or more pieces are often spliced together at the site to form one long single bar. The following are three methods that ITD allows to splice rebar.

Lap Splices
Lap splices are formed when two bars are overlapped for a certain length and tied together. The length of the overlap is called the lap length and is specified in the Project Plans. A sufficient lap length is needed to adequately transfer loads between the bars. Lap lengths can be longer than specified, but never shorter. Inadequate lap length can cause severe cracking in the concrete around the lap.

Reinforced concrete is typically its weakest around the lap splices in the primary reinforcement bars. For this reason, lap splices are placed in areas where the stresses in a reinforced concrete section are the lowest. The Inspector must ensure that the Contractor laps reinforcing steel only in the places specified in the Project Plans and with sufficient lap length. If the Contractor wishes to move a lap splice, the Designer must approve the location change. In areas of high bending and tensile stresses, the Department should insist on using continuous bars or either mechanical or welded splices.

Lap splices can present problems with concrete cover and clearance between bars. Lap splices must have adequate concrete cover for corrosion protection just like continuous bars. It is important to ensure that the spacing between the lap splices allows for the adequate flow of concrete around the splice. Sometimes the lap splices in a group of bars are staggered to reduce congestion at the splice location.

Designers and Contractors have joint responsibility to ensure that lap splices are workable in terms of spacing and adequate cover. The Designers need to ensure that lap splices will fit within the dimensions of a concrete member. Concrete cover must be adequate and rebar clearance must take into account a reasonable coarse aggregate size. If lap splices do not work, alternatives such as resizing the member, stagger splices, or a different splice detail should be specified. Contractors, on the other hand, have a responsibility to identify congested rebar sections on the Project Plans and adjust their concrete mix design accordingly. They also have a responsibility to place lapped bars well within the allowable placement tolerances when congestion at a lap splice is a problem.

Non-Contact Lap Splices
When a precast member is structurally connected to a cast-in-place concrete member or another precast member, the rebar from both members is lap spliced together to ensure adequate stress transfer across the two members. Sometimes due to the positioning of the precast member or because of placement tolerances in the reinforcing steel, the lapped bars do not end up touching each other at the splice. In other words, there is a gap between the

two bars at the lap splice. The Designer must approve any *non-contact laps* that are not shown on the Project Plans.

When non-contact laps are permitted, the bars must not be spaced too far apart or a zigzag crack in the concrete may develop between the bars. Usually the gap is limited to the lesser of 1/5 the lap length or 6 inches (150 mm). Non-contact laps are generally permitted in secondary reinforcement and in some minor structures. However, they should not be allowed as an alternative to chronically poor workmanship.

Mechanical Couplers

When mechanical couplers are used to splice rebar, the couplers must be submitted to the Department ahead of time for approval.

For each type of mechanical coupler used, the Inspector should have the manufacturer's recommendations on how to make field splices. It is part of the Inspector's job to verify that the Contractor is following the manufacturer's recommendation for making mechanical splices.

It is also the Inspectors responsibility to sample mechanical couplers in accordance with the standard specifications and any special provisions. The samples must be taken at random and after the splices have been made. The Contractor is entitled to no additional costs for providing samples of mechanical splices used for testing or for the cost of repairing the rebar where the samples have been taken.

Welded Splices

Butt-welded splices are the only acceptable welded splices.

Changing the Type of Rebar Splice

For placement reasons, safety reasons, or for other constructability reasons, Contractors may want to use mechanical couplers or welded splices in place of lap splices. Again the Department and Designer must approve the splice changes.

Just because lap splices are shown, doesn't mean the Contractor is limited to this type of splice. The Contractor must choose the appropriate type of splice based on how he or she intends to construct the work. Changing lap splices to mechanical couplers or welded splices should be at no cost to the Department since the Standard Specifications clearly allow the Contractor other splicing options. The Contractor's selection of a different splicing option is not a changed condition unless the Project Plans or Special Provisions specifically preclude other splicing options.

Welding Rebar

Most rebar is specified as ASTM A615 steel. There are no strict controls on the chemical composition of the steel as long as the desired mechanical properties are met. Because there are no strict chemical controls, heating this type of steel for welding or cutting purposes can adversely alter the chemical composition of the steel. The steel can become permanently weakened and brittle due to the applied heat and the subsequent method of cooling.

When welding is permitted, ASTM A706 steel must be used and the welding must be performed by an American Welding Society (AWS) certified welder.

The welder should have the correct mill test report (chemical analysis) from the heat in which steel was made. Welding procedures do change to reflect the actual chemical composition of the steel. This test report should be included in the Certificate of Analysis.

The welding of stressed reinforcing steel may be permitted if such welding conforms to AWS D12.1, "*Recommended Practices for Welding Reinforcing Steel, Metal Inserts, and Connections in Reinforced Concrete Construction*."

Tack welding of non-stressed reinforcing steel is permitted when approved by the Resident Engineer. Tack welding of stressed reinforcing steel is NOT permitted. In ordinary slab-and-girder construction, only the top longitudinal slab steel is non-stressed. In column construction, all longitudinal steel is stressed; ties are non-stressed. In ordinary reinforced concrete beams, girders, and pier and bent caps, all top and bottom longitudinal steel is stressed; stirrups are generally stressed; small longitudinal bars which are not a part of top or bottom reinforcement groups are generally non-stressed. In precast, prestressed concrete girders, stirrups are generally stressed; longitudinal non-prestressed steel is generally non-stressed although there are exceptions. Steel in footings is generally stressed. Steel in the outer faces of retaining walls, wing walls, and parapets is generally non-stressed. Vertical steel at the inner faces of parapets and the earth faces of retaining walls and wing walls is generally stressed. Exceptions are always possible. When a stressed reinforcing bar terminates with a hook, the extreme end of the bar at the hooked end may be considered non-stressed.

No welding should be performed near prestressing strands without protecting the cable from welding splatter. Even the slightest nick or burn mark in the strands is enough to cause failure during tensioning.

Epoxy-Coated Reinforcement

When epoxy-coated steel reinforcement is specified, Inspectors need to be watchful in how the Contractor handles the bars. Scratches, nicks, and other damage must be repaired. Don't allow the Contractor to mishandle the rebar with the intent of fixing any damage to epoxy coating later. Repair procedures should only be allowed for the occasional accident.

For the epoxy coating to prevent rebar corrosion, the entire bar supports (i.e. chairs, tie wires, and mechanical couplers) must be corrosion proof. It makes no sense to support an epoxy-coated bar on a bare-metal chair. The Resident Engineer and Materials Section must pre-approve all bar supports, couplers, and tie wires for epoxy-coated rebar. The Contractor should submit samples and product literature well in advance of any placement work.

It is the Department's policy not to allow any metal bar supports or metal tire wire (coated or uncoated) for epoxy coated rebar in concrete barrier wall. Non-metallic supports and tie wire must be used since the steel in a barrier wall is highly susceptible to corrosion.

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Protection of Material

Steel which is to be stored at the job site for an extended period should be protected from the weather to prevent excessive rusting. If covers are used to protect the steel, be sure to provide ventilation to prevent trapping of moisture in the enclosure.

A slight rust coating on the bars has little effect on the strength or on the bond to the concrete. Heavy rust pitting could materially reduce the cross-sectional area of the bar and should be cause for rejection.

Oil and grease, including form oil, act as bond breakers. When this gets on the bars, the Inspector has no choice but to insist upon its removal. Removal may be done with petroleum-based solvent such as naphtha, gasoline, or diesel fuel. A hand-held torch can be used to lightly heat up the bar and burn off oil, grease or paint.

Loose mortar, curing compound, dirt, and mud can weaken the bond between the steel and concrete. The steel should be wiped or washed clean of these contaminants. In severe cases, wire brushing may be needed especially on any primary reinforcement. Mill scale can be removed by sand blasting or in limited amounts by wire brushing.

Tolerances for Cutting, Bending and Placing

In the cutting, bending, and placing of reinforcing steel, it is recognized that it is not reasonable to require all bars to be cut, bent, and placed precisely as shown on the Project Plans. On the other hand, the strength of each member of a structure is dependent upon the cutting, bending, and placing being within reasonable tolerances. Because of these facts, the Department has adopted allowable tolerances that are considered reasonable and practical to meet yet will not significantly reduce the strength of the structural member below the theoretical design strength.

Cutting and Bending Tolerances

The following tolerances are based on industry standards established by the Concrete Reinforcing Steel Institute (refer to Chapter 6 of *Placing Reinforcing Bars*):

1. Cutting to length on straight bars: ± 1 inch (25 mm).
2. Hooked bars, out-to-out: ± 1 inch (25 mm).
3. Truss bars, out-to-out: ± 1 inch (25 mm). The height (H) or drop (rise): ± 1/2 inch (13 mm).
Bend down points and bend up points shall be within 2 inches (50 mm) of position indicated on the Project Plans.
4. Spirals or circles ties, out-to-out dimension: ± 1/2 inch (13 mm).
5. Column ties or stirrups, out-to-out dimension: ± 1/2 inch (13 mm).

Bars that are consistently too short or consistently bent to the wrong dimensions are cause for rejection. Improper cutting and bending can also result in failure to meet placement tolerances in the forms.

Placing Tolerances

The effectiveness of the reinforcement and the strength of the structure are dependent upon the reinforcing bars being placed in the concrete in nearly the exact position shown on the Project Plans. If they are not placed as shown, the structure will likely not have the strength that the Designer anticipated. For example; when the depth of all truss bars in a structural concrete member is 1/2 inch (13 mm) less than shown on the Project Plans, the strength of that member is reduced from 15 to 25 percent.

The correct position of the steel, in relation to the tension face of the concrete, is of great importance. If it is too far away from the face, the strength of the member will be adversely affected. If the position is too close, particularly in bridge decks, water and de-icing chemicals penetrate to the steel and cause it to rust. The rusting process causes an expansion in the volume occupied by the steel that will cause spalling of the concrete.

The following table of permissible variations from plan location or spacing shall be used as a guide in determining good construction practice for placement of reinforcing steel. Substantial conformance to these values is required.

	Beams	**Slabs**	**Walls**	**Piers & Columns**
Clearance from forms**	1/4 in. (6 mm)	1/4 in. (6 mm)	1/4 in.*** (6 mm)	1/4 in. (6 mm)
Spacing between top & bottom bars	------	1/4 in. (6 mm)	------	------
Spacing between parallel bars*	1/4 in. (6 mm)	1 in. (25 mm)	1 in. (25 mm)	1 in. (25 mm)
Placement of bars length-wise & location of bend points***	1 in. (25 mm)	2 in. (50 mm)	------	------
Stirrup projection above top of beams	2 in. (13 mm)	------	------	------
Stirrup and hoop spacing	1 in. (25 mm)	------	------	1 in. (25 mm)

* The number of bars in any 4 ft. (1.2 m) of distance shall equal the number called for on the plans.

** End cover shall not be less than 1 in. (25 mm.)

*** **1**/2 in. (13 mm) for walls more than 8 in. (200 mm) thick.

A final check must be made just prior to concrete placement to insure that the re-bar is properly positioned and is held securely in place. Specifications require that the deck-finishing machine be operated over the full length of the bridge deck prior to concrete placement. This is the time to check the top steel for proper cover. The force exerted by concrete as it moves into final position can move individual bars, mats, or cages out of position very easily. Top layers of re-bar in bridge decks must be tied down per each 16 ft2 (1.5 m2) of deck area. Cages in walls must be securely attached to the forms, not freestanding or spaced with temporary blocks. Metal chairs bend quite easily when stepped on. They require constant checking during the placement. Ensure that no steel is displaced by runways, accidents, dumping concrete, etc. Due to the low slump deck concrete, it is conceivable that the reinforcement could be displaced upward during the necessary vibrating operation. Constant attention is required to detect and correct any displacement of reinforcement. Also check on other items such as anchor bolts, inserts, pipe sleeves, conduits, etc.

Documentation for Pay Quantities

Most reinforcing steel is paid for on a weight basis or is included in the cost of another contract item. Rarely is a contract setup to pay reinforcing steel on a lump sum basis. However, when there is a quantity dispute or additional work under a lump sum payment provision, the weight basis should be used to measure reinforcing steel to equitably adjust the contract amount.

The Inspector should collect the cut sheets that accompany each steel shipment and note any quantities used for placements, aids, or left out of the structure. The date and time the steel was placed in the structure should be noted. This process should not be much different than collecting concrete tickets, where the Inspector tracks the concrete quantities, placement location, and waste.

Tracking steel quantities as steel is placed is important for heading off quantity disputes. Often these disputes arise because the quantity shipped to the project is different than the quantity shown in the bidding schedule or Project Plans. However Inspectors need to keep in mind that there is a yield factor that applies to rebar similar to the yield factor that applies to ready mixed concrete. With rebar, there are end pieces that are not used, bars that are used as placement aids, and waste from rebar cutting. Sometimes even extra bars are sent at the Contractor's request to replace damaged bars previously shipped.

Inspectors don't need to document every single bar placed in a structure, but they do need to scrutinize cut sheets and other shipping documents and note any quantity discrepancies as steel is placed.

The Concrete Inspector should calculate the quantities of metal reinforcement before construction begins. If the total quantity for each item is within one percent (1%) of the plan quantity, no additional checking is necessary. If the difference is greater, the calculations should be checked further in the residency. The Contractor and Supplier should be informed immediately of any errors discovered during this checking. These computations and checks should be included as part of the project records and will be the source document for the final pay quantity of these items. The above-mentioned calculations should show the quantity to be paid for each portion of the structure. Quantities for payment of metal reinforcement shall be computed to the nearest pound (0.5 kilogram).

The diary shall be used to verify the activity, date, and location of work. Photographs of the steel placement should be taken for further documentation and project information.